CAPTURING TAGGED RED SALMON WITH PULSED DIRECT CURRENT

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by

Richard B. Thompson
Fishery Research Biologist

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U. S. Fish and Wildlife Service
Seattle, Washington

ABSTRACT

The equipment, installation, and techniques of operation of an experiment to collect individual fish from schools of migrating adult red salmon *(Oncorhynchus nerka)* in Alaska with pulsating direct current are described. Electrodes were installed in the river in the path of the salmon. Current was turned on as the selected fish passed between the electrodes. Fish between the electrodes were forced to move towards the positive electrode, placed in slack water 3 feet deep close to shore. As they encountered the denser electrical current, the fish were electronarcotized and final capture was made with a long-handled dip net. Trial collections resulted in capturing 83 percent of the individual fish for which attempts were made. Tests to determine optimum pulse frequencies and duty cycles indicated that frequencies between 60 and 140 per second and duty cycles between 40 percent and 85 percent gave good results. A pulse rate of 90 per second at 80-85 percent duty cycle gave the best general results.

Separation of Asian and North American stocks of salmon on the high seas is one of the most pressing problems now facing biologists working on research and management of our salmon resources. Red salmon, *Oncorhynchus nerka,* is one of the most important fish species involved.

In 1956 a full-scale tagging program was undertaken on the high seas for the American Section of the International North Pacific Fisheries Commission. The Fisheries Research Institute of the University of Washington was awarded contract No. 14-19-008-2424 by the U.S. Fish and Wildlife Service (since continued by the Bureau of Commercial Fisheries) to conduct a high-seas salmon tagging program. Recovery of a tagged fish on its upstream migration would indicate the natal side of the Pacific for that fish.

In the 1958 tagging and recovery operations, 13,000 fish were tagged and released at a total cost of $256,000. The 1958 recovery was 112 tagged fish; the 1959 recovery, from the same lot, was 57. It is possible that more will be received from Asiatic waters, raising the total recoveries to an estimate of 200. Some minor additional returns of tags in 1960 from all areas are expected. Thus, it is indicated that each recovered tag will have cost about $1,300 in actual expenditures. The value of a recovered tag, because of the few recoveries and

the need for information, exceeds this figure.

Most of the salmon tags are recovered in the intense commercial fisheries in bays and estuaries as schools of salmon approach the mouths of their spawning streams. However, in 1959 the important Bristol Bay, Alaska, commercial red salmon fishery was to be drastically reduced to allow enough escapement to provide adequate seeding of the spawning grounds by the expected small run. Because of this reduction in the fishery, other methods of tag recovery had to be devised. One of these methods was the use of electrical fish-shocking apparatus described in this paper.[1]

In the main tributary rivers of Bristol Bay, schools of red salmon follow rather restricted routes of migration, which are not in the fast water in the main portion of the river but are usually fairly close (6 to 25 feet) to shore in 3 to 8 feet of water, thus making them accessible to an electrofishing installation. This habit of the salmon has been utilized in the "tower method" of salmon enumeration as they ascend the trunk rivers.[2]

MATERIALS AND METHODS

The electrofishing experiment was conducted at Igiugig Camp of the Fisheries Research Institute (fig. 1), on the Kvichak River about 1 mile below the outlet of Lake Iliamna, where the river is about 300 to 500 feet across. The Institute observers in the counting towers, one on each side of the river, counted the salmon as they pass over light-colored panels laid on the river bottom.

The fish used in the tests of the electrical method were members of the naturally migrating schools of red salmon as they passed the electrofishing installation. Certain individuals within the schools were specifically identified by gill-net marks, early development of spawning coloration, or by isolation. During the height of the run some fish were captured, tagged, and released near the installation area by the Institute personnel; these tagged fish were occasionally utilized as test fish as they continued their upstream migration. Either white or red and white tags were put on the salmon on the high seas. Tags used within the Kvichak system by the Institute were of solid colors other than red and white, and were of larger diameter than the high-seas tags. Therefore, there was little chance of confusion of the source of the tagged fish seen.

With the use of the direct-current shocker, efforts could be made to recover all tags passing the installation. Fish bearing undesired tags could be released unharmed to continue their migration upstream. In this operation efforts were made to capture all tagged fish which might bear a high-seas tag.

During the test operations attempts were made to capture individual fish from all areas within the usual migration path and from all positions within the schools of fish. This was done as objectively as possible. Tagged fish would be

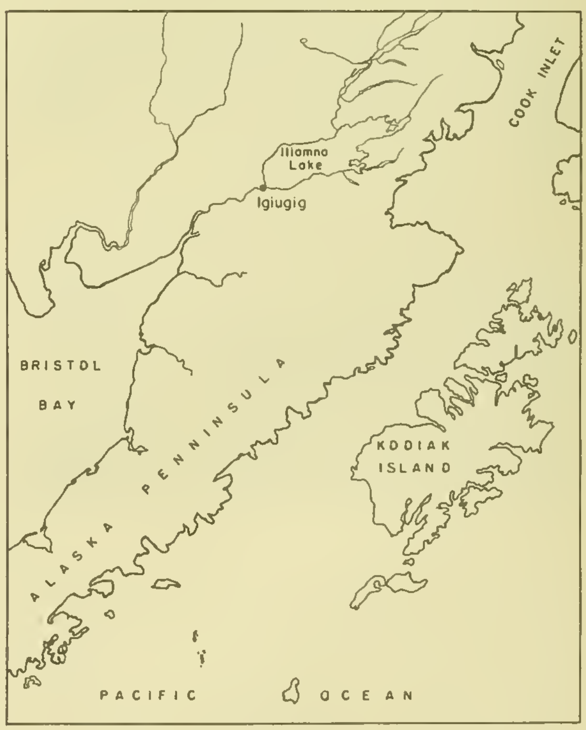


Figure 1.--Location map of Igiugig electrofishing site.

[1] Immediately prior to the opening of the fishing season in Bristol Bay permission was granted the commercial fleets for a more liberal and extensive fishing operation. Plans for the electrofishing tag-recovery effort proceeded as an experimental operation for possible future applications.

[2] Fisheries Research Institute. 1959. Report of Operations, 1958. College of Fisheries, University of Washington, March, 24 pp.

randomly distributed within the schools of passing fish, and it was desired to determine the efficiency of capturing any specific fish that migrated upstream.

Electrodes were panels of screening, 3 feet wide and 8 to 25 feet long, installed flat on the river bottom in the usual path of migrating fish. The negative electrode was in the offshore position; the positive electrode, to which fish are attracted by the pulsing direct current, was closer to shore. As the selected tagged fish passed between the electrodes the current was turned on, forcing the fish towards the positive electrode, where, in the denser electrical field, it was narcotized in a more accessible position in shallow, quieter water. Final capture was accomplished with a long-handled dip net. It was possible to allow the remainder of the school to escape unharmed, for direct current causes no harm unless fish are burned by direct contact with the electrode.

The object was to move a specific fish into the vicinity of the positive electrode by means of the pulsing current (electrotaxis) and to immobilize or render it unconscious (electronarcotized) in the immediate vicinity of the positive electrode.

The equipment necessary for this operation consists of a portable generator (as a power source), pulsing and current-control unit, lead wires to the electrodes from the pulser, the electrodes themselves, and a long-handled dip net or spear to make the final capture.

The generator used was a modified Homelite Model 24D230, which produced 2,500 watts of direct current at 230 volts. The generator has been modified with capacitors and resistors to match its output to the Type III transitorized pulsing and control unit of the Fish and Wildlife Service.

The Type III pulser and control unit was produced for the Predator-Competitor Investigations by the Fisheries Instrumentation Laboratory, both located at the Seattle Biological Laboratory, Bureau of Commercial Fisheries, U.S. Fish and Wildlife Service. The transistorized pulser is an elaborated version of the Type II pulser described by Dale.[3] This pulser produces square-wave pulsations of direct current at 230 volts. Frequencies of pulsation adjustable from 2 to 200 per second are available. Duty cycles, that is, the percentage of on-time within a full pulse, are available between 30 and 90 percent. Superposition of a high-cycle pulsation and a low-cycle pulsation results in bursts of pulses or double modulation of the pulse pattern.

A remote push-button control switch is provided to operate the pulse unit to send the pulsed current to the electrodes. Releasing the button opens the control circuit and turns off the current to the electrodes.

The fish shocker apparatus was first installed on the north bank of the Kvichak River, 100 yards upstream from the Institute's No. 1 counting tower. The electrodes extended out into the river perpendicular to the bank from where the depth of water was about 3 feet to where it was 8 feet deep, a distance of about 30 feet. The negative electrode was placed downstream of the positive electrode so that there was a distance of 10 feet separating the two. These electrodes were laid flat on the river bottom under the path of the salmon migration.

At this location it was necessary to have at least a 3-man crew for optimum operation. From an elevated position where he could observe the fish, one man operated the push button that energized the electrodes. In a boat, one man attempted to capture the narcotized fish with a dip net upon signal from the operator while the other controlled the boat.

At camps where counting stations have been operated, manpower availability is usually limited. With this in mind, another location was sought where one man could operate the entire collecting system; that is, observe the passage of fish, operate the generator and pulsing unit, and make the recovery of the tagged fish.

The site was located just below a small eddy which was formed by the main river current flowing around a small rocky point (fig. 2). The migration path of the salmon followed within 10-15 feet of the shoreline

[3]Dale, Harry P. Electronic fishing with underwater pulses. Electronics, vol. 32, No. 4, pp. 31-33, January 1959.

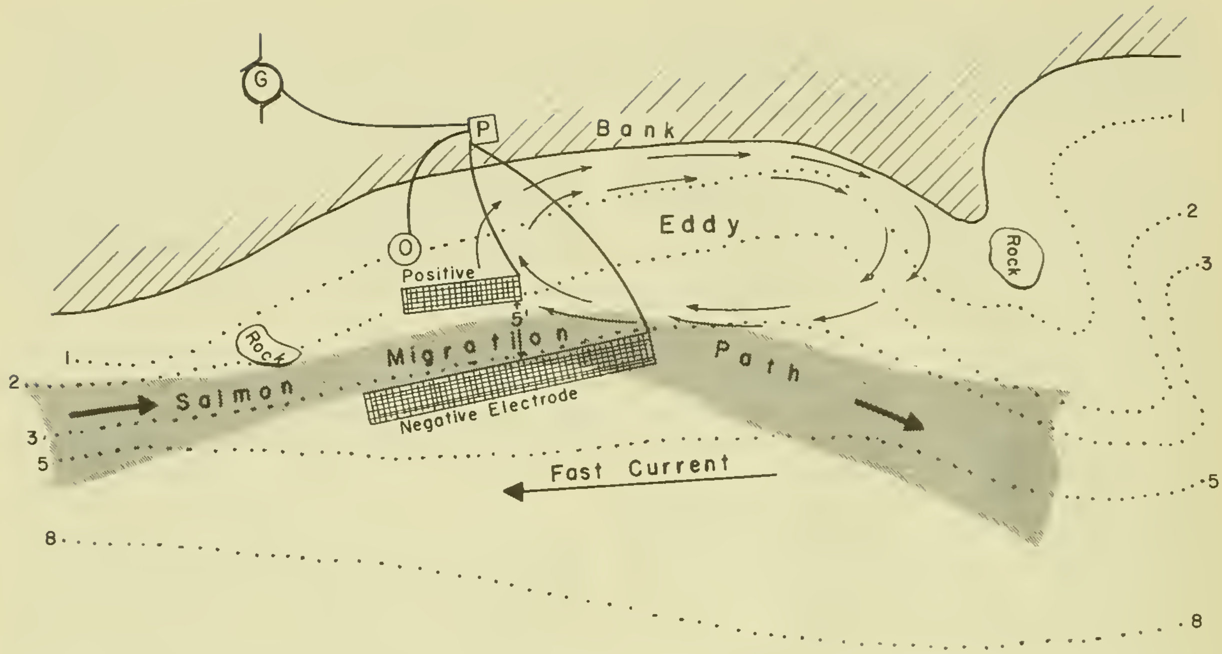


Figure 2.--Site No. 2 Installation, showing salmon migration path and positions of positive and negative electrodes. Dotted lines indicate approximate depth contours (in feet). G, generator; P, pulser and control unit; O, operator with on-off switch and long-handled dip-net.

as the fish approached the eddy. The fast current in the main part of the river caused the fish to follow a narrow path, 3 to 5 feet wide, about 10 feet offshore in 4 feet of water at the lower edge of the eddy. As they encountered the edges of the slack and reverse currents of the eddy, the fish, rather than to follow this route, pushed out into faster water to get around the small point.

It was here at the lower end of the eddy, where the migration path was at its narrowest and closest to shore, that the electrodes were installed for Site No. 2.

The electrodes at the second site consisted of wire fencing material, 3 feet wide, fabricated of 10-gauge wire in 2- by 3-inch meshes. The positive electrode was of two layers of this wire, about 8 feet long, placed inshore with its inner edge in about 3 feet of water, while the negative electrode was of one layer, about 25 feet in length, placed offshore parallel to the river current (fig. 2). The electrodes were separated by a space of about 5 feet, held in position on the river bottom by rocks attached to the upper surfaces, and were positioned so that the undisturbed schools of fish passed between them.

The operator had a good view of the approaching and passing fish from where he was standing, about knee keep in water just inshore of the positive electrode. With the push-button operating switch, he could turn on the electrode current at the proper time to capture the tagged fish.

A dip net with hoop diameter of 2 feet and with a 10-foot aluminum handle was used for final capture of stunned fish. The net was held in a vertical position along the operator's right side with the hoop uppermost. When the tagged fish was pulled inshore by pulsing direct current toward the positive electrode, the net was lowered into the water to retrieve the fish, which was immobilized at the positive electrode about 6 to 8 feet from the operator. The pulsed direct current during this time was turned on and off for the optimum control of the fish by use of the push-buttom switch held in the left hand along with the dip-net handle.

RESULTS

The results of electrofishing for the capture of specific marked salmon at Site No. 1 were only marginally successful. The depth of the water hindered the

recovery of a fish even when it was held down against the positive electrode by pulsing direct current. Location of the fish with respect to the electrodes prior to shocking was quite critical in the efficiency of electrical control and capture of the fish. Frequently, as schools passed the installation the particular fish selected in test operations would not pass through the optimum location between electrodes. Two men were necessary and three were desirable for operating the gear.

At this location, the efficiency achieved in these tests was about 30 percent, or 3 out of 10 attempts to capture the tagged fish were successful. It was decided that this was inadequate to warrant further use of the electrofishing device at this site.

Operation at the second site was better in all respects. Reduction of necessary manpower, water-current characteristics (depth, speed, "edge" between fast and slow water), and migration path (depth, width, distance offshore) all contributed to a more efficient operation. The only shortcoming was the lack of advance observation of the migrating fish, which could have been easily offset by the construction of an elevated observation tower 50 to 75 yards downstream. When the operator sighted a tagged fish, he could proceed to the shocker site, start the generator, and be in position to shock and collect the fish as it came between the electrodes. Thus, with the shocker installed in this location, one man could operate the whole collection system.

After preliminary tests in which optimum frequencies and duty cycles were determined (see below), efforts to collect 65 specific fish were made. Fifty-four, or 83 percent, of the specific fish sought were captured. Efforts were made to capture fish from the outer fringes of the migration path as well as the center, since a tagged fish might appear at any number of locations within the general migration path. Most failures occurred when the selected fish was on the outer edge of the migration path and over the offshore edge of the negative electrode. Almost 100 percent success was achieved in the test series if the selected fish in each test was located between the energized electrodes.

No high-seas tagged salmon were observed to pass the electrofishing installation during operating hours. The tower counts were conducted for 20 minutes of each hour. Additional hours were spent in observation for tagged fish during the height of the migration, but no high-seas tagged salmon were observed to pass the towers. Subsequent spawning-ground surveys by the Fisheries Research Institute personnel resulted in the recovery of two spaghetti-type high-seas tags from the Iliamna Lake spawning population of 680,000 red salmon.

Optimum Pulse Frequencies and Duty Cycles

Figure 3 illustrates the general reactions of the adult red salmon to various pulse-frequency rates and duty cycles.

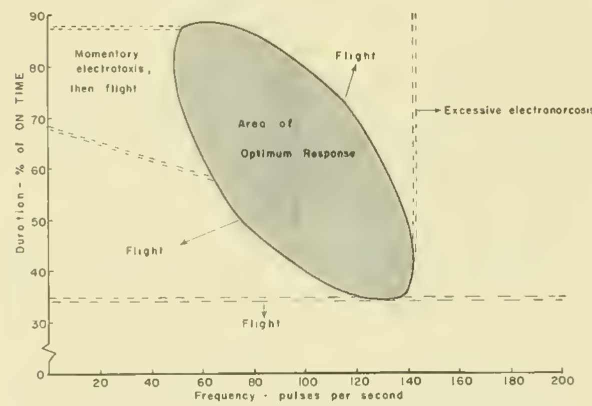


Figure 3.--Responses of adult red salmon *(Oncorhynchus nerka)* to various combinations of square-wave pulse frequencies and duty cycles. "Optimum Response" explained in text.

Referring to figure 3, it is seen that use of square-wave pulses of more than 140 per second caused immediate paralysis of the fish with no electrotaxis toward the positive electrode. The immobilized fish, still in the river current, were carried away from the operator's net. Duty cycles of less than 35 percent at all frequencies resulted in insufficient control of the fish, causing only flight from the electrodes, usually at a very high speed. Usually, pulse frequencies below 60 per second, except at higher duty cycles, also caused fish to escape. In this low-frequency range at duty cycles above about 65 percent, some short reactions of electrotaxis were illustrated. However, the fish seemed to adjust to the pulsating electrical current,

regained control of their movements, and escaped.

The water of the Kvichak was found to be very soft and highly resistant, having a measured resistance of 41,000 ohms per centimeter cube. It was found that in such highly resistant water, the line between over-control (that is, immediate narcosis without electrotaxis) and optimum control was so fine that it was not possible to ascertain it exactly under the conditions of this experimental operation.

Optimum Shocker Site Characteristics

As evidenced by the different efficiencies achieved at the two experimental sites, the characteristics of an electrofishing installation can have an appreciable effect on the efficiency of collection. In this respect, the second site appeared almost optimum. The characteristics of a good shocker site are as follows:

1. Current: Fast enough in the main river to cause the migrating fish to choose a narrow path fairly close to shore in slower water. A sharp "edge" between fast and slow water is desired.

2. Depth: The depth at the path of migration should not be over 5 feet, the bottom sloping upwards toward shore so that the positive electrode is in water not greater than 3 feet. If the positive electrode is positioned just under the surface, it is suspected that the location would not be too critical: up to a 10-foot maximum depth.

3. Conductivity: As high as possible; but since little can be done about this within a given river system, it must be accepted as an independent characteristic.

4. Observation: A fairly high bank downstream from the shocker site would facilitate observation for the tagged fish; otherwise, an elevated platform should be constructed from 50 to 100 yards downstream.

DISCUSSION

The experimental operations described here have indicated some feasibility in capturing tagged or individually identifiable fish from a migrating school of red salmon.

The apparatus was originally developed for a quite different purpose than the use to which it was put in this experiment. Crude field adaptations for the electrode system were made using available materials. Refinements in the equipment, based on experience achieved during this field operation, could substantially improve efficiency. The increment in efficiency of the operation at Site No. 2 over Site No. 1 indicated how field experience could improve the selection of location, installation of the gear, and techniques of operation. Additional experience and improved electrode systems should further increase the ability of the apparatus to capture tagged salmon. Sections of expanded aluminum screening, perhaps lightly anodized and dyed a full color for camouflage, would make better electrodes than the materials used. Three or four of these 4- by 8-foot panels linked together would serve as a negative electrode, and 1, or possibly 1/2 of a section, as the positive electrode.

It might also be better to suspend the positive electrodes just under the surface of the water by floats or a supporting framework, rather than on the stream bottom. An electrode in contact with the bottom allows much of the current to pass through the streambed, where it has no effect on the fish. Having the positive electrode suspended closer to the surface could also serve to bring the fish into a better position for netting. Such installation of the electrode, even though it would be more visible to the fish, should not have a frightening effect on the fish. Floating A-frames on the river surface, used as "ripple dampeners", for improving visibility from the counting towers, had no effect on the passage of fish. Moored boats and floats adjacent to the migration path were observed to have no effect on the fish passing close by, as long as these objects were stationary. Moving objects frightened the fish, but man-made stationary objects, even brightly colored or shiny, had no effect on the passage of fish. In fact, during the important parts of the run, fish appear to be oblivious to all objects around them.[4]

The use of electrofishing methods to capture specific fish in Bristol Bay rivers

[4] Thompson, W. F., and D. W. Clancy. 1959. Length measurement of migrating salmon by paired underwater cameras. Photogrammetric Engineer, vol. 25, No. 3 (June), pp. 449-455.

would, because of manpower availability and expense, have to be incorporated with the counting tower operations. In such an arrangement, it would be possible to have the equipment installed and in a constant state of readiness, so that the person making counts and observations from the tower could operate the shocker and capture the tagged fish. One generator and one pulser could be used for electrode operations on both sides of the river. A battery-powered starter would provide for repaid remote starting of the generator by observers on either tower. A switch could connect the power source with the desired set of electrodes. With the generator operating and the proper set of electrodes connected, a switch could be thrown to energize the electrodes when the selected tagged fish was in the right location. When the operator saw that the fish had been pulled into the anode and electronarcotized, he would descend the tower and make the final capture of the fish with a long-handled dip net. The remainder of the fish in the area would be allowed to escape; no harm would be caused to them by the direct current.

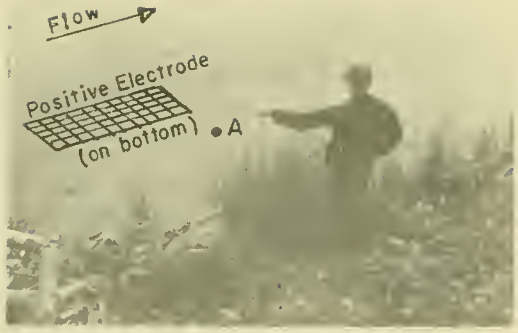
Some minor disruption of the rate of migration of the schools of fish was caused by the use of the shocker. During testing operations the shocker was operated extensively, at times for 30 seconds every 5 minutes. The violent attempted-evasion antics of the fish in the electrical field (fig. 4) would cause fish further downstream to slow down, and some to turn around and go downstream. From 2 to 5 minutes would elapse before the migration would assume its normal rate. Reactions of fish to the current and alarm movements of fish attemping to evade the electrical field varied with density of the migration. When small schools of fish were separated by distances of 30 yards or more, the effect of the disturbance was greater and a longer time passed before the normal movement of fish resumed. When there was a steady stream of migrating fish the disruption was less, and a shorter time elapsed before they resumed their normal rate of movement. Same disruptions of migration were observed when boats passed over the path of migration, and the time before resumption was the same with either the boat or electrical shocker disturbance.

Once the equipment has been installed and testing operations completed, the use of the electrofishing apparatus probably would be limited to tag recoveries; thus, the effect of the machine on the rate of migration would be negligible. The high value of a recovered tag would make the possibly slight loss of accuracy of fish counts from the towers during tag-recovery efforts insignificant.

The visibility of the fish would have some effect on the efficiency of the shocker, as poor visibility would effect any operation with fish where they must be observed. Usually, when surface light is low or ripples distort subsurface visibility, the tag is seen before the fish itself is visible. At any time when visibility is adequate for fish counting from the towers, it is sufficient for electrical collection of fish. When the electrodes are energized and the fish in the area are disturbed, causing further water-surface distortion, it may be difficult to keep the tagged fish in sight. However, with a proper electro-system lying astride the migration path, the electrical control of the fish should be good and they should be forced to swim towards the anode. There, in shallower water, the fish would be easily visible.

As mentioned earlier, a tagging program was being conducted at Igiugig by the Fisheries Research Institute. Red salmon were captured in the river, tagged, and released with the intent to determine the distribution of the fish on the spawning grounds of Kvichak River. Most fish tagged were captured by beach-seining in the river near the counting towers. However, at times the fish would not be available at these seining grounds. Attempts to capture fish for tagging purposes were made with the electrofishing apparatus. At Site No. 2 these attempts proved quite successful. The one man operating the shocker apparatus was able to provide fish to keep a two-man tagging crew continuously supplied. After tagging, the fish were released at the shocker site and allowed to proceed on their way to the spawning grounds.

Subsequent recovery on the spawning grounds indicated that equal percentages



Frame 1

5

2

6

3

7

4

Figure 4.--Prints from 16 mm. motion-picture film illustrating reactions of adult red salmon in electrical field at Site No. 2. Frame 1 was exposed at instant electrodes were energized. Subsequent frames show action at 1/2-second intervals. Note how majority of fish within electrical field are headed towards positive electrode. Operation shown here was for picture-taking purposes only. Collecting operation was done with operator in knee-deep water (point A) with dip net in right hand for final capture of fish.

of seine-caught and shocker-caught tagged fish were recovered. This illustrates that shocker-caught fish suffered no significantly different harm from the method of collection than did the seine-caught fish. Such an electrofishing apparatus could be used to capture live, unharmed salmon for a variety of purposes.

The initial cost of an electrofishing installation for tag recovery would be approximately $1,500. This would provide for a battery-starting generator, a pulsing and control unit, the electrode systems necessary for covering both banks of a river, and the supplemental switches and wiring to complete the installation. However, if such a unit captured even one high-seas tagged salmon that would not have been captured otherwise, the cost would be justified. Under the conditions of use described here and with proper off-season storage, the life of the generator and pulsing unit should be well over 10 years, materially reducing the cost per year. In addition, use of the apparatus for other live-fish collecting purposes would further justify the initial cost of the instrument.

After a short period of indoctrination and experience in the field, say 1 week, one man at each station would be sufficiently proficient in the operation and use of the apparatus to proceed independently with its operation. Malfunction of the pulsing unit in the field, once the particular model is perfected, should be negligible. At the time this experiment was performed, the pulser, a new prototype, had been field-used only for 5 months, and still contained some imperfections. These have been corrected and the unit has since been operating without malfunction under more rigorous field conditions than those encountered in this experiment.

On the basis of the results achieved in this experimental operation, it is felt that further use and development of the technique is warranted, provided that similar extrinsic factors, such as the reduced commercial fishery and the value of the recovered tag, exist.

APPENDIX

Figure 4 is included to illustrate pictorially the reactions of red salmon to the electrical current. The prints are enlargements of 16 mm. colored motion-picture frames, exposed at 24 frames per second. Each printed frame was 12 frames from the preceding one, thus the time interval between prints was 1/2 second.

By following one fish through a series of frames one can see how the fish reacted to pulsing direct current. Some of the fish visible at the water surfaces near the fringe of the electrical field can be seen escaping. But those which were between the electrodes when they were energized can be seen approaching the location of the positive electrode under control of the electrical current and being electronarcotized well within reach of the operator's dip net. In the operator's hand is the on-off push button which sent the current to the electrodes.

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